

**REFLECTIVE TYPE-FRINGE FIELD SWITCHING MODE LCD****FIELD OF THE INVENTION**

5 The present invention relates to a reflective type liquid crystal display, more particularly to a reflective-type fringe field switching mode LCD(hereinafter, reflective FFS-LCD) capable of improving a reflection rate thereof.

10 **BACKGROUND OF THE INVENTION**

A twisted nematic(TN) mode LCD having nematic liquid crystal compositions of positive dielectric anisotropy has been used for the conventional reflective type LCD. This reflective type TN-LCD has a low power consumption property and is used for relatively small size LCDs of an electronic clock, a digital clock and so on. However, the reflective TN-LCD has chronic problems of a poor viewing angle and a low contrast ratio.

Consequently, a reflective FFS-LCD device is now in the process of research and development to ensure a good viewing angle property, a high reflective rate and an aperture ratio. The composition of this conventional reflective FFS-LCD device is approximately illustrated in FIGs. 1 and 2.

Referring to FIGs. 1 and 2, a lower substrate 10 is opposed to an upper substrate 15 at a selected distance. A liquid crystal layer 17 having a plurality of liquid crystal molecules is interposed between the lower substrate 10 and the upper substrate 15. A counter electrode 11a and a pixel electrode 11b forming a fringe field to operate the liquid crystal molecules, are disposed on the inside surface of the lower substrate 10. A color filter(not shown) is disposed on the inside surface of the upper substrate 15. A first homogeneous alignment layer 12 is interposed between the lower substrate 10 including the counter electrode 11a and the pixel electrode 11b, and the

liquid crystal layer 17. A second homogeneous alignment layer 16 is interposed between the upper substrate 15 including the color filter and the liquid crystal layer 17. At this time, the first and the second homogeneous alignment layers 12, 16 have rubbing axes R1, R2 respectively, and the rubbing axis R1 of the first homogeneous alignment layer 12 and the rubbing axis R2 of the second homogeneous alignment layer 16 form  $180^\circ$ , i.e. anti-parallel to each other. In addition, the rubbing axis R1 forms a selected angle with a line f which on the substrate surface, projects the fringe field that is formed between the counter electrode 11a and the pixel electrode 11b. A polarizer 8 is attached on the outside surface of the upper substrate 5 so that polarizing axis 8a thereof is equal to the rubbing axis R1 of the first homogeneous alignment layer 12. A  $\lambda/4$  plate 19 polarizing an incident light or a reflected light by  $\lambda/4$  is disposed on the outside surface of the lower substrate 10. On the outside of the  $\lambda/4$  plate 19, a reflective plate 20 reflecting the light which passes through the  $\lambda/4$  plate 19, is disposed. At this time, the  $\lambda/4$  plate 19 is disposed so that a fast (or slow) axis thereof is at an angle of  $45^\circ$  with the first rubbing axis (R1).

Such conventional reflective-type FFS-LCD operates as following.

First, referring to FIG. 1, when voltage difference does not occur between the counter electrode 11a and the pixel electrode 11b, the liquid crystal molecules (not shown) are arranged so that the rubbing axes R1, R2 and the long axes thereof are parallel. Consequently, a natural light 22a becomes an incident light 22b proceeding to the same direction as a polarization axis 18a by passing through a polarizer 18. Thereafter, the direction of the incident light 22b is not changed while passing through the liquid crystal layer 17 which the rubbing axes R1, R2 and the long axes of the liquid crystal molecules are arranged

side by side thereon. The incident light 22b which has passed through the liquid crystal layer 17, is at an angle of  $45^\circ$  with the fast(or slow) axis of the  $\lambda/4$  plate 19, thereby becoming a right-circularly polarized light 22c passing through the  $\lambda/4$  plate 19. The right-circularly polarized light 22c is reflected by a reflective plate 20, thereby becoming a right-circularly polarized reflected light 23a.

The reflected light 23a becomes the reflected light 23a proceeding to a crossing direction with the axis of the polarized light 18a, passing through the  $\lambda/4$  plate 19 having the fast(or slow) axis at an angle of  $45^\circ$  with the proceeding direction thereof. The proceeding direction of the reflected light 23b which has passed through the  $\lambda/4$  plate 19, is orthogonal to the long axis of the liquid crystal layer 17, thereby passing through the liquid crystal layer 17 without being changed. The reflected light 22b which has passed the liquid crystal layer 17, is orthogonal to the polarizing axis 18a, thereby not passing through the polarizer 18. Accordingly, a screen becomes dark.

Next, like FIG. 2, when a fringe field F is formed between the counter electrode 11a and the pixel electrode 11b, the liquid crystal molecules(not shown) are twisted into the fringe field form. Consequently, the optical axes of the liquid crystal molecules(not shown) are at a selected angle with the polarizing axis 18a. A natural light 25a passes through the polarizer 18, thereby becoming an incident light 25b proceeding to the same direction as the polarizing axis 18a. Thereafter, the incident light 25b is at an angle of  $45^\circ$  with a long axis of a liquid crystal molecule which is arranged in a fringe field F form. Therefore, an incident light 25c which has passed through the liquid crystal layer 17, becomes the incident light 25c which is at an angle of  $45^\circ$  with the polarizing axis 18a. Here, the incident light 25c which has passed through the

liquid crystal layer 17 coincides with the fast(or slow) axis 19a of the  $\lambda/4$  plate 19, thereby passing through the  $\lambda/4$  plate 19 without change in the proceeding direction thereof. The incident light 25c which has passed through the  $\lambda/4$  plate 19, is reflected by the reflective plate 20, thereby becoming a reflected light 26a.

The proceeding direction of the reflected light 26a coincides with the fast(or slow) axis of the  $\lambda/4$  plate 19, thereby passing through the  $\lambda/4$  plate 19 without changing the proceeding direction thereof. The proceeding direction of the reflected light 26a which has passed through the  $\lambda/4$  plate 19, is at an angle of  $45^\circ$  with the long axis of the liquid crystal molecule on the liquid crystal layer 17 and therefore the proceeding direction of a reflected light which has passed through the liquid crystal layer 17, coincides with the polarizing axis 18a. Therefore, a screen is in a white state.

Conventional reflective type liquid crystal display device has not required a backlight as light source and optical component such as the  $\lambda/4$  plate 19 has been added to the outside of a substrate thereof to improve a contrast.

However, the manufacturing cost is increased as the optical component such as the  $\lambda/4$  plate is added. Moreover, the  $\lambda/4$  plate absorbs some of an incident light or a reflected light, thereby deteriorating transmissivity of the LCD, i.e. the reflectance.

#### SUMMARY OF THE INVENTION

Accordingly, an object of this invention is to provide a reflective type liquid crystal display device having a good contrast ratio and a good reflectance without an additional optical component.

To accomplish the aforementioned object of this invention, the present invention according to a first embodiment provides a reflective type FFS-LCD including: a

liquid crystal layer having a plurality of the liquid crystal molecules; a first substrate disposed on one side of the liquid crystal layer and in which a counter electrode and a pixel electrode, both for generating a fringe field to drive the liquid crystal molecules are formed; a second substrate disposed on the other side of the liquid crystal layer; a first homogeneous alignment layer interposed between the liquid crystal layer and the first substrate and having a rubbing axis in a selected direction; a second homogeneous alignment layer interposed between the liquid crystal layer and the second substrate, and having a rubbing axis in a selected direction; a polarizer disposed on an out side of one of the first substrate and the second substrate, and having a selected polarizing axis; and a reflective plate disposed on an out side of the other of the first substrate and the second substrate, wherein retardation of the liquid crystal layer is  $(2n+1)\lambda/4$  (here,  $\lambda$  is wave of light and  $n$  is a positive number).

The present invention according to another embodiment, also provides a reflective type FFS-LCD including a liquid crystal layer having a plurality of liquid crystal molecules; a first substrate disposed on one side of the liquid crystal layer and on which a counter electrode and a pixel electrode, both for generating a fringe field to drive the liquid crystal molecules are formed; a second substrate disposed on the other side of the liquid crystal layer; a first homogeneous alignment layer interposed between the liquid crystal layer and the first substrate and having a rubbing axis in a selected direction; a second homogeneous alignment layer interposed between the liquid crystal layer and the second substrate and having a rubbing axis in a selected direction anti-parallel to the rubbing axis of the first homogeneous alignment layer; a polarizer disposed on an out side of one of the first substrate and

the second substrate, and having a selected polarizing axis; and a reflective plate disposed on an out side of the other substrate of the first substrate and the second substrate, wherein the rubbing axes of the first and the second alignment layers are at an angle of 10 to 85° with a substrate projection line of the fringe field, wherein retardation of the liquid crystal layer is  $(2n+1)\lambda/4$  (here,  $\lambda$  is wave of light and  $n$  is a positive number).

#### 10      **BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a perspective view showing a conventional reflective type FFS-LCD when electric field is off.

FIG. 2 is a perspective view showing a conventional reflective type FFS-LCD when a fringe field is applied.

15      FIG. 3 is a perspective view of a reflective type FFS-LCD according to a first embodiment of this invention.

FIG. 4 is a plan view of a lower substrate according to the first embodiment of this invention.

20      FIG. 5 is a drawing describing operation of a reflective type FFS-LCD according the first embodiment of this invention when the electric field is off.

FIG. 6 is a drawing describing the operation of a reflective type FFS-LCD according to a first embodiment of this invention.

25      FIG. 7 is a perspective view of a reflective type FFS-LCD according to a second embodiment of this invention.

FIG. 8 is a drawing describing operation of a reflective type FFS-LCD according to the second embodiment of this invention when the electric field is off.

30      FIG. 9 is a drawing describing operation of a reflective type FFS-LCD according to a second embodiment of this invention when a fringe field is applied.

35      FIG. 10 is a graph showing a reflectance in accordance with a retardation( $d\Delta n$ ) in a reflective type FFS-LCD accordance with this invention.

FIG. 11 is a graph showing a contrast ratio according

to an azimuth in a reflective type FFS-LCD of this invention.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

##### 5      A FIRST EMBODIMENT: A REFLECTIVE TYPE FFS-LCD OF NORMALLY WHITE TYPE

FIG. 3 is a perspective view of a reflective type FFS-LCD according to this invention. Referring to FIG. 3, a lower substrate 40 is opposed to an upper substrate 60 with  
 10 a selected distance  $d_{11}$  (hereinafter, cell gap). A liquid crystal layer 65 including a plurality of liquid crystal molecules 65a, is interposed between the lower 40 substrate and the upper substrate 60. At this time, a liquid crystal molecule 65a of the liquid crystal layer 60 is nematic, and  
 15 dielectric anisotropy may be positive or negative. In this embodiment, for example, material of positive dielectric anisotropy is used. And, retardation of the liquid crystal layer 65, i.e. the product of the cell gap  $d_{11}$  and the index of refraction anisotropy of the liquid crystal  
 20 molecule 65a, is  $(2n+1)\lambda/4$ .

A counter electrode 43a and a pixel electrode 46a are disposed on the inside surface of the lower substrate 40 so as to form a fringe field to drive the liquid crystal molecule 65a. Here, the inside plane structure of the lower  
 25 substrate 40 on which the counter electrode 43a and the pixel electrode 46 is formed, is presented in FIG. 4. Referring to FIG. 4, a plurality of gate bus lines 41a, 41b are extended and arranged to an x direction of a drawing with a selected interval on the lower substrate 40. And, a  
 30 plurality of data bus lines 47a, 47b are also extended to a y direction of a drawing with a selected interval on the lower substrate 40, thereby defining a unit pixel with the gate bus lines 41a, 41b. In a drawing, only a pair of gate bus lines 41a, 41b and a pair of data bus lines 47a, 47b are  
 35 illustrated. A gate insulating layer 44 is sandwiched between the gate bus lines 41a, 41b and the data bus lines

47a,47b thereby insulating themselves from each other. A common signal line 42 is extended to some direction, for example, to the x direction, and located between a pair of the gate bus lines 41a,41b. For example, it is desirable  
5 that the common signal line 42 is disposed in a location closer to the previous gate bus line 41b than gate bus line 41a selecting a pixel. Here, to shorten RC delay time, the gate bus lines 41a,41b, the common signal line 42 and the data bus lines 47a,47b are formed out of a metal layer or  
10 more than two alloy layers among groups which are composed of Al, Mo, Ti, W, Ta, Cr having relatively good conductive property and combinations thereof.

A counter electrode 43 is formed at each unit pixel of the lower electrode 43. Here, the counter electrode 43 is  
15 formed on the surface of the lower substrate 40 and formed so as to be contacted with the common signal line 42. The counter electrode 43 is contacted with the common signal line 42 and therefore applied of the common signal. At this time, the counter electrode 43 includes a plurality of  
20 branches 43a which are extended parallel with the data bus lines 47a,47b, and a body part 43b connecting groups of the branches 43a. At this time, the body part 43b is in part contacted with the common signal line 42. Here, the respective branches 43a have a selected width P11 and are  
25 spaced each other with a selected distance L11. The width P11 and the distance L11 of the branches 43b are decided by considering the width of a pixel electrode and the distance with a pixel electrode which will be formed later.

A pixel electrode 46 is also formed at each unit pixel  
30 of the lower substrate 40. At this time, the pixel electrode 46 is formed on a gate insulation layer 44 so as to be overlapped with the counter electrode 43. The pixel electrode 46 includes strips 46a which are respectively disposed between the branches 43a of the counter electrode  
35 43 and a bar 46b which is overlapped with the body part 43b of the counter electrode 43 connecting groups of the strips





overlapped. This storage capacitor Cst acts to maintain data signal during a frame.

Meanwhile, a color filter(not shown) is arranged on the inside surface of the upper substrate 60.

5 And, a first alignment layer 53 is formed on the resultant of the lower substrate 40, and a second alignment layer 63 is formed at an inner surface of the color filter on the upper substrate 60. The first and the second alignment layers 53,63 have the surfaces on which liquid  
10 crystal molecule 65a is arranged to a selected direction. The first and the second alignment layers 53,63 are the homogeneous alignment layers which are treated so that the liquid crystal molecule has a pretilt angle of 0 to 10°, and have the rubbing axes R1,R2 respectively. Here, the  
15 rubbing axis R1 of the first alignment layer 53 is at a selected angle( $\Psi$ ) with the direction of an x axis(hereinafter, projection line of a fringe field). At this time, the angle which the rubbing axis R1 of the first alignment layer 53 and the direction of the x  
20 axis(hereinafter, projection line of a fringe field) form, is adjusted in the range of 10 to 85° according to the dielectric anisotropy so as to obtain the maximum transmissivity. The rubbing axis R2 of the second alignment layer 63 is anti-parallel to the rubbing axis R1 of the  
25 first alignment layer 53, that is, rubbed so as to have the angle difference of about 180°.

And, a polarizer 70 is disposed on the outside surface of the upper substrate 60, and a polarizing axis 70a is disposed parallel to the rubbing axes R1,R2. A reflective  
30 plate 75 is disposed on the out side of the lower substrate 40. At this time, the reflective plate 75 acts to reflect an incident light to 180°.

And, an optical component such as a  $\lambda/4$  plate which has been added to conventional reflective type FFS-LCD, is not  
35 added to the reflective type FFS-LCD of this invention. Instead, the liquid crystal layer 65 serves as  $\lambda/4$  plate by

adjusting retardation of the liquid crystal layer 65.

The reflective FFS-LCD of this invention having this composition operates as following.

First, when the gate bus line 41a is not selected, the  
5 signal of the data bus line 47a is not transmitted to the  
pixel electrode 46b, therefore a fringe field between the  
counter electrode 43 and the pixel electrode 46b is not  
formed. Consequently, a long axis is parallel to the  
rubbing axes R1,R2 so that the liquid crystal molecules 65a  
10 within the liquid crystal layer 65 are arranged almost  
parallel to a surface of a substrate. Then, a natural light  
100a, as illustrated in FIG. 5, becomes an incident light  
100b proceeding to an equal direction to the polarizing  
axis 70a by the polarizer 70. The incident light 100b  
15 passes through the liquid crystal layer 65 which is  
arranged so that the rubbing axes R1,R2 and the long axis  
of the liquid crystal molecule are equal, and the  
proceeding direction thereof is not changed. The incident  
light 100b which has passed through the liquid crystal  
20 layer 65, is reflected by the reflective plate 75, thereby  
becoming a reflected light 110a.

The reflected light 110a passes through the liquid  
crystal layer 65 again and the proceeding direction thereof  
is not changed. Consequently, the proceeding direction of  
25 the reflected light 110a is equal to the polarizing axis  
70a of the polarizer 70, thereby passing through the  
polarizer 70. Accordingly, a screen is in a white state.

Meanwhile, when a scanning signal is transmitted to the  
gate bus line 41a and a display signal is transmitted to  
30 the data bus line 47a, a thin film transistor 50 which is  
formed near a crossing point of the gate bus line 41a and  
the data bus line 47a, is turned on and therefore  
transmitted to the pixel electrode 46. At this time, a  
common signal having a different voltage from the display  
35 signal is continuously applied to the counter electrode 43,  
and therefore a fringe field F is formed between the

counter electrode 43 and the pixel electrode 46 and on the upper of the electrode 43,46. Furthermore, when the fringe field  $F$  is projected to the lower substrate 40, the fringe field  $F$  and polarizing axis 70a make a selected angle.

- 5 Consequently, the liquid crystal molecule 65a is arranged so that the fringe field and the long axis or the optical axis thereof are parallel. Therefore, retardation occurs in the liquid crystal layer 65 by  $(2n+1)\lambda/4$  (here,  $n$  is a positive number).

- 10 Then, a natural light 200a, as illustrated in FIG. 6, becomes an incident light 200b equal to the polarizing axis by passing through the polarizer 70. The incident light 200b which has passed through the polarizer 70 passes through the liquid crystal layer 65 having retardation of  
 15  $(2n+1)\lambda/4$ , and therefore the proceeding direction thereof is changed, thereby becoming a right-circularly polarized incident light 200c. The right-circularly polarized incident light 200c is reflected by the reflective plate 75, thereby becoming a reflected light 210a being right-  
 20 circularly polarized.

- The reflected light 210a becomes a reflected light 210b orthogonal to the polarizing axis 70a by retardation of the liquid crystal layer 65 again. Consequently, a screen is in a dark state. Therefore, a display can be realized by  
 25 normally white method without the  $\lambda/4$  plate.

**EMBODIMENT 2: REFLECTIVE TYPE FFS-LCD BY NORMALLY BLACK METHOD**

- 30 FIG. 7 is a perspective view of a reflective type FFS-LCD according to a second embodiment of this invention. In this embodiment, a structure of the lower substrate 40, a structure of the upper substrate 60, the liquid crystal layer 65 and the reflective plate 75 are equal to those in  
 35 the first embodiment and only disposition of the polarizer 70 is different. A polarizing axis 70b of the polarizer 70

is at a selected angle, preferably  $45^\circ$ , with the rubbing axes R1,R2 so that a reflective FFS-LCD according to this embodiment, as illustrated in FIG. 7, is operated by a normally black method.

5        Operation of this reflective FFS-LCD by the normally black method is described.

First, before a fringe field is formed, long axes of the liquid crystal molecules 65a coincide with the rubbing axes R1,R2 and are arranged almost parallel to the substrates. Then, a natural light 300a, as illustrated in FIG. 8, by the polarizer 70, becomes an incident light 300b proceeding to an equal direction to the polarizing axis 70a. The incident light 300b is at an angle of  $45^\circ$  with the long axis of the liquid crystal molecule, thereby becoming an incident light 300c proceeding to an equal direction to the rubbing axes R1,R2, passing through the liquid crystal layer 65. The incident light 300c which has passed through the liquid crystal layer 65 is reflected by the reflective plate 75, thereby becoming a reflected light 310a.

20        The proceeding direction of the reflected light 310a is at an angle of  $45^\circ$  with the long axis of the liquid crystal molecule 65a, thereby becoming a reflected light 310b orthogonal to a polarizing axis 70b, passing through the liquid crystal layer 65. The proceeding direction of the reflected light 310b which has passed through the liquid crystal layer 65 is perpendicular to the axis of the polarized light 70b, thereby not passing through the polarizer 70. Accordingly, a screen is in a dark state.

Meanwhile, when a fringe field F is formed, the liquid crystal molecule 65a is arranged so that the fringe field F and the long axis or the short axis thereof are parallel, and therefore retardation occurs in the liquid crystal layer 65 by  $(2n+1)\lambda/4$  (here, n is a positive number). A natural light 400a, as illustrated in FIG. 9, becomes an incident light 400b equal to the polarizing axis 70b by passing through the polarizer 70. The incident light 200b

which has passed through the polarizer 70 is equal to the long axis of the liquid crystal molecule 65a which is twisted by the fringe field F, thereby passing through the liquid crystal layer 65 without changing its polarization state. An incident light 400c which has passed through the liquid crystal layer 65 is reflected by the reflective plate 75, thereby becoming a reflected light 410a.

The reflected light 410a is equal to the optical axis of the liquid crystal molecule 65 which is arranged in a fringe field form, thereby passing through the liquid crystal layer 65 without changing its polarization state. The proceeding direction of the reflected light 410a which has passed through the liquid crystal layer 65 is equal to the polarizing axis 70b, thereby passing through the polarizer 70. Accordingly, a screen is in a white state. Consequently, a display can be realized by the normally black method without using the  $\lambda/4$  plate.

FIG. 10 of accompanying drawings is a graph showing reflectance in accordance with retardation ( $d\Delta n$ ) in a reflective type FFS-LCD according to this invention. According to FIG. 8, when  $\lambda$  is 550nm, the points which reflectance are 0 and 0.9 show periodically. At this time, at the point of 0 retardation is  $(2n+1)\lambda/4$  and at the point of 0.9 retardation is  $2n/\lambda$ . Consequently, when retardation of the liquid crystal layer 65 is  $(2n+1)\lambda/4$ , a display can be realized without the  $\lambda/4$  plate.

FIG. 11 is a graph showing contrast ratio according to azimuth in a reflective type FFS-LCD of this invention. According to FIG. 11, when polar angle ( $\theta$ ) is more than  $30^\circ$ , contrast ratio is more than 10, and therefore good contrast ratio can be obtained without the  $\lambda/4$  board.

This invention is not limited to the embodiments as described above.

For example, according to the embodiments of this invention, the pixel electrode and the counter electrode

are formed in the comb forms. However, being not limited to this, the pixel electrode and the counter electrode can be formed in any form so as to form a fringe field.

- 5 A reflective type FFS-LCD of this invention has effects as following.

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10 First, in reflective type FFS-LCD, retardation( $d\Delta n$ ) uses material having retardation of  $(2n+1)\lambda/4$  as the liquid crystal layer. Consequently, the liquid crystal layer serves as a conventional  $\lambda/4$  plate, thereby not requiring to form an extra  $\lambda/4$  plate. Accordingly, intensity of light increases and price decreases.

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15 Moreover, the liquid crystal molecules between the counter electrode and the pixel electrode and on the upper of the electrodes, are all operated by the fringe field, and therefore reflectance of a reflective type FFS-LCD is further improved.

- 20 Various other modifications will be apparent to those skilled in the art and can be easily carried out without departing from the spirit and the scope of the present invention as defined by the accompanying claims.